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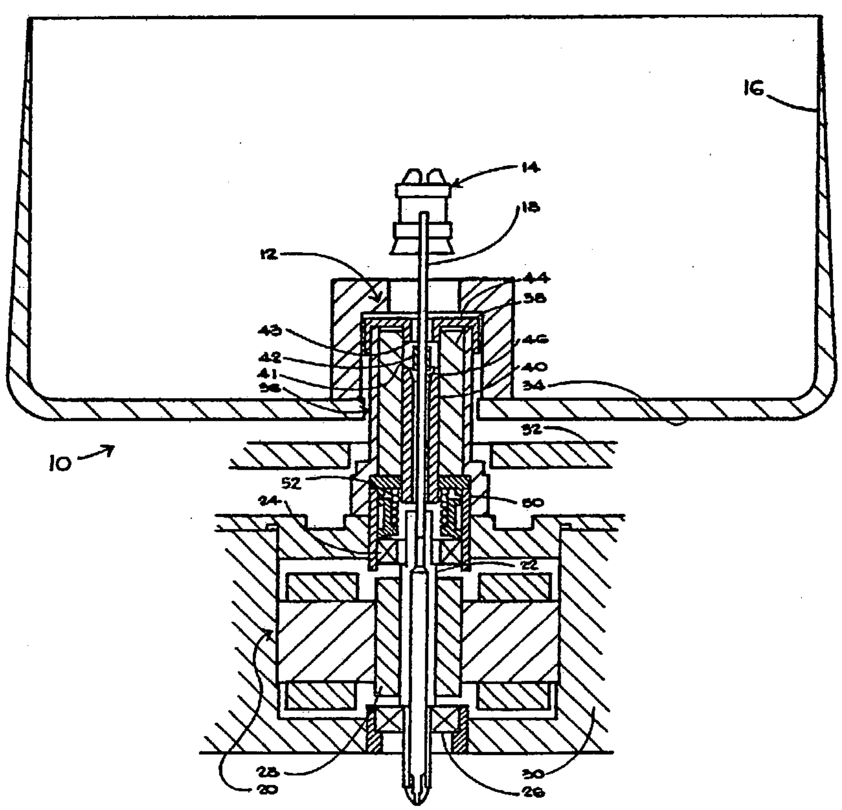
(54) Title: CENTRIFUGE STABILIZING BEARING

(57) Abstract

A stabilizing bearing designed to selectively operate to provide lateral support to a small diameter drive shaft (18) used in a small ultracentrifuge. The stabilizing bearing (40, 42) is preferably operated by the use of a solenoid (38) to move the bearing (40) into place to provide lateral support to the thin drive shaft (18) when it might otherwise flex at low speeds, causing vibration and possible detrimental effects to the desired centrifugal separation of the fluid sample in the rotor. The activation of the stabilizing bearing is automatic in response to a specified speed parameter of the drive shaft.



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CENTRIFUGE STABILIZING BEARING

Background of the Invention

The present invention is directed to ultracentrifuges and, more specifically, is directed to a stabilizing bearing for use on an ultracentrifuge thin drive shaft.

It should be noted that in the manufacture of a centrifuge drive spindle which connects the rotor with the driving mechanism, the spindle is made relatively thin in order that it have the requisite flexibility for successful operation. Two primary reasons exist for flexibility in the drive spindle. First, when a user is operating a rotor, it is very important that the rotor be properly balanced with the test samples that are placed within the rotor tube cavities. However, often the operator does not achieve the correct balance and there will be slight imbalance in the samples within the rotor which will cause a slight unbalanced condition in the operation of the rotor. A slight flexing of the drive spindle can accommodate this imbalance and relieve stress on the high speed bearings.

The second reason for flexibility in the drive spindle relates to slight geometric limitations in the machining for the making of the rotor drive shaft and the driving mechanism. It is not possible, due to restrictions in machining capabilities, to make an ideal, exactly perfect geometrically aligned rotor drive shaft and driving mechanism. Although nearly perfect, the arrangement for the ultracentrifuge is such that even the slightest geometric imperfection caused by limitation in the machining will become apparent with respect to ultracentrifuge operation. Therefore, a flexible shaft is

necessary in order to relieve some of the stress which would occur, especially in the bearing area of the machine as a result of rotor unbalance or slight geometric imperfections. Therefore, the drive shaft is made relatively thin in order to accomplish the desired flexibility.

However, a thin drive shaft has a natural frequency or critical speed which occurs at a relatively low speed. At this point the drive shaft will experience vibration. When possible unbalanced conditions or slight geometric imperfections combine with the shaft's critical frequency, the vibration is accentuated to cause possible detrimental deflection and bending in the shaft. Consequently, it is important during this critical speed of the shaft to stabilize the shaft so that this frequency does not cause deflection of the shaft. Otherwise, the shaft would continue to deflect or oscillate in such a manner that it may result in damage to the entire centrifuge.

One solution to this problem would be to use a damper bearing on this thin shaft at all times. However, the damper bearing would have to be designed for high speed operation as well as low speed operation. In high speed operation certain aspects such as dynamics and lubrication must be addressed which will complicate the design.

Summary of the Invention

The present invention is directed to a movable stabilizing bearing mounted adjacent the drive shaft to provide selective support to the drive shaft during certain phases in the operation of the centrifuge. The preferable arrangement of the present invention utilizes a bushing surmounted on the shaft which is activated by a

solenoid to move it into and out of bearing engagement with the shaft to provide lateral support to that shaft. The operation of the solenoid or any other type of activating device is in response to a specific speed of the rotor shaft.

By utilizing the stabilizing bearing for engagement with the shaft at its critical speed, the natural or critical frequency of the shaft is raised. Therefore, no vibration will occur in the shaft during the time frame and speeds that the stabilizing bearing is supporting the shaft. However, once the speed of the shaft is above its natural critical speed, the removal of the stabilizing bearing will result in no vibration occurring, because the shaft will be operating higher than its natural critical frequency.

As stated previously, during the startup of the centrifuge, the rotor goes from zero to its operational speed; however, at some point it will reach its natural critical frequency where vibration may occur. In a thin diameter shaft it may be a range of, for example, approximately 700 RPM's. Consequently, in the design of an embodiment of the present invention the stabilizing bearing will automatically be engaged with the drive shaft from zero up to a speed of approximately 1,000 RPM. As the shaft goes through its natural frequency which is somewhere between zero and 1,000 RPM's, the stabilizer bearing will provide a stiffening effect which in essence gives the shaft an artificially higher natural frequency to prevent vibration at these lower speeds. Once the speed exceeds 1,000 RPM's, the solenoid operated stabilizing bearing will disengage, allowing the shaft to operate at higher speeds and at that point the shaft will be above its natural frequency and no vibration will occur. Similarly, when the centrifuge run has been com-

pleted and the rotor is slowing down, the stabilizing bearing will automatically be activated when the speed is reduced to 1,000 RPM's until the rotor completely stops.

The engagement of the stabilizing bearing only at speeds less than 1,000 RPM's simplifies the design of the bearing, because it does not have to accommodate dynamics and lubrication complications as required with high speed bearings.

Brief Description of the Drawings

Figure 1 shows a vertical sectional view of a centrifuge drive assembly incorporating the stabilizing bearing of the present invention with the stabilizing bearing in the disengaged position; and

Figure 2 shows a partial vertical sectional view of the drive assembly with the stabilizing bearing of the present invention in the engaged position.

Detailed Description of the Invention

Figure 1 shows a centrifuge 10 having a drive spindle assembly 12 with a hub assembly 14 which projects into a rotor chamber 16. The hub assembly 14 is designed to receive a rotor (not shown). The drive spindle 18 extends downward from the hub assembly for connection with an induction motor assembly 20. Located in the induction motor is an armature shaft 22 which engages an upper high speed bearing 24 and a lower high speed bearing 26. Surmounted on the armature shaft 22 is the armature 28 of the induction motor 20.

The induction motor 20 has a housing 30 which is mounted below the drive mount plate 32. Both the drive mount plate 32 and the induction motor housing 30 are located below the bottom 34 of the rotor chamber 16.

The shaft 18 in the present invention is preferably a very small diameter drive shaft which is for some centrifuge assemblies as small as approximately .078 inches. This shaft is used to drive a relatively small ultracentrifuge rotor having a diameter as small as approximately four inches. Consequently, the drive shaft 18 is susceptible to flexing due to its function as a coupling between the rotor and the bearings 24 and 26. Also, the shaft may be subjected to flexing caused by rotor imbalance and geometric limitations in the manufacturing methods of the centrifuge.

Located above the induction motor arrangement 20 and above the upper high speed bearing 24 is the stabilizing bearing assembly 36 comprising a solenoid coil 38 and a bushing 40 which is slidably mounted on the drive shaft 18. Affixed to the drive shaft 18 is a collar or sleeve 42 which is designed for bearing engagement with the bushing 40 when it is activated to move up toward the cap 44 of the drive spindle assembly 12. The bushing 40 has an interior diameter which is slightly greater than the exterior diameter of the drive shaft 18, so that the bushing is freely movable longitudinally along the drive shaft 18. When the bushing 40 is moved into bearing engagement with the collar 42, the top 41 of the bushing will contact the bottom 43 of the cap 44. The upper portion of the bushing 40 has a tapered opening 46 to provide guidance over the collar 42 when the bushing is moved toward the cap 44.

Located between the solenoid operated bushing 40 and the induction motor 20 is a lower housing assembly 50 which is designed to secure the induction motor armature shaft 22 in place with the high speed bearings 24 and 26. This proper alignment is maintained by the use of the spring 52 in this cap arrangement 50.

In the operation of the present invention, a rotor containing fluid samples for centrifugation is placed on the hub assembly 14. The drive shaft 18 is connected through the armature shaft 22 to the induction motor 20 which provides the driving mechanism for rotation of the shaft 18 which, in turn, operates the rotor. During operation, the rotor will tend to spin about its own geometric center which may be slightly out of alignment with the armature shaft 22. Also, the rotor may be slightly unbalanced if the operator was not careful in loading the samples into the rotor. Consequently, the drive shaft 18 will flex in order to accommodate these inconsistencies.

In certain centrifuges, the drive shaft 18 is very thin and too much flexing may cause some problem with respect to the integrity of the shaft. This problem is accentuated at the critical speed of the shaft where natural vibration will occur. In rotor operation it is necessary to avoid the generation of detrimental vibrations on the rotor which could disturb the separated constituents in the rotor and in severe situations may cause damage to the centrifuge. It has been found that the critical speed for a very thin shaft normally occurs at a relatively low speed while the rotor is either going from zero speed to its operational speed or decelerating from its speed at operation to its stationary position. By way of example, it has been found that a rotor shaft of the diameter of approximately .078 inches will vibrate at a critical point during its acceleration or deceleration at some point between zero and 1,000 RPM.

Therefore, as shown in Figure 2, when the drive motor in the centrifuge begins to operate, the solenoid 38 is automatically activated to move the bushing 40 of the stabilizing bearing into position around the collar

42. The stabilizing bearing 36 with its bushing 40 provides support to the rotor shaft 18 and will prevent the occurrence of any vibration as the shaft goes through its critical or unstable speed. The stabilizing bearing provides support by absorbing energy transmitted from the shaft similar to the operation of a damper bearing or a bumper bearing.

The control system for the solenoid 38 operates automatically in response to the speed of the shaft 18. In most cases, once the rotor and the shaft exceed 1,000 RPM's, the stabilizing bearing will be automatically deactivated, since at that point the shaft will be above its vibrational frequency range and will provide a smooth rotative motion. After the deactivation of the solenoid 38 vibration in the shaft and the force of gravity will cause the freed bushing 40 to move away from the cap 44 and disengage from the collar 42 as shown in Figure 1. When the centrifuge run has been completed, the rotor will decelerate and, when it reaches the speed of 1,000 RPM's, the stabilizing bearing will again automatically be activated by the solenoid to move the bushing 40 up around the collar 42 to create the necessary stiffening of the shaft 18 as it again passes through its critical vibrating or frequency point below 1,000 RPM's.

An alternate embodiment of the present invention would incorporate the use of a ball bearing arrangement which would move into and out of engagement with the collar 42. The ball bearing would provide in some instances a better bearing for the shaft than the use of the bushing 40. It is envisioned that any type of bearing arrangement could be used in conjunction with the present invention of selectively engaging the bearing with the shaft for added support at critical speeds.

What is claimed is:

1. A centrifuge assembly comprising:
   a chamber (16) for receiving a rotor;
   a drive shaft (18) projecting into the chamber for connection to the rotor;
   driving means for spinning the shaft;
   a support member (40) for the shaft adjacent its connection to the rotor when the shaft is spinning below a specified speed; and
   activating means (38) to selectively move the support member in response to a comparison of the speed of the shaft and the specified speed.

2. A centrifuge assembly as defined in claim 1, characterized in that the support member comprises a damper bearing.

3. A centrifuge assembly as defined in claim 2, characterized in that the damper bearing comprises a bushing slidably mounted on the shaft and movable between a first position and a second position.

4. A centrifuge assembly as defined in claim 2, characterized in that the damper bearing comprises a ball bearing surmounted on the shaft and movable between a first position and a second position.

5. A centrifuge assembly as defined in claim 3, characterized in that the damper bearing additionally comprises a collar (42) attached to the shaft.

6. A centrifuge assembly as defined in claim 5, characterized in that the actuating means comprises a solenoid which moves the bushing between the first and second positions, the bushing in the first posi-

tion not contacting the shaft, the bushing in the second position contacting the collar on the shaft to stiffen the shaft during rotation below the specified speed.

7. A centrifuge assembly as defined in claim 1, characterized in that the specified speed is approximately 1,000 RPM.

8. A centrifuge assembly as defined in claim 1, characterized in that the activating means moves the supporting means between a first position and a second position, the supporting means in the first position engaging the shaft to dampen vibrations when the shaft is rotating below the specified speed, the supporting means in the second position disengaged from the shaft.

AMENDED CLAIMS

[received by the International Bureau on 10 October 1983 (10.10.83); original claims 1–8 have been replaced by new claims 1–5]

1. A stabilizing bearing assembly (36) for damping vibrations in the drive shaft (18) of a centrifuge when the shaft is rotating below a specified speed in a centrifuge having a chamber (16) for containing a rotor, a hub (14) for coupling the rotor to the drive shaft (18), drive means for driving the drive shaft, characterized by:

a circular collar (42) affixed to the drive shaft (18);

an elongated bushing (40) slidably disposed over the drive shaft (18), the bushing having an inside diameter dimensioned to fit over the collar (42) and the bushing (40) being slidable between a first position in which it is disposed over the collar (42) and a second position in which the bushing is disengaged from the collar (42);

actuating means for moving the bushing (40) to the first position when the drive shaft is rotating below a specified speed.

2. The stabilizing bearing assembly (36) defined by claim 1 wherein the actuating means for moving the bushing (40) to a first position comprises a solenoid coil (38) encircling the bushing.

3. The stabilizing bearing assembly (36) defined by claim 1 further including a cap (44) disposed over the upper end of the solenoid coil (38) and having a central opening through which the drive shaft (18) extends and a bottom surface (43) adjacent the collar (42);

the bushing (40) abutting the bottom surface (43) of cap (44) when the bushing is in the first position.

4. The stabilizing bearing assembly (36) defined by claim 1 further including the bushing (40) having at the upper end thereof a bevel (46) in the entrance of the inside diameter of the bushing (40) to guide the bushing into engagement with the collar (42) when the bushing enters the first position thereof.

5. The stabilizing bearing assembly (36) defined by claim 1 wherein the bushing (40) being returned from the first position to the second position by the effect of gravity acting thereon when the actuating means are not energized.

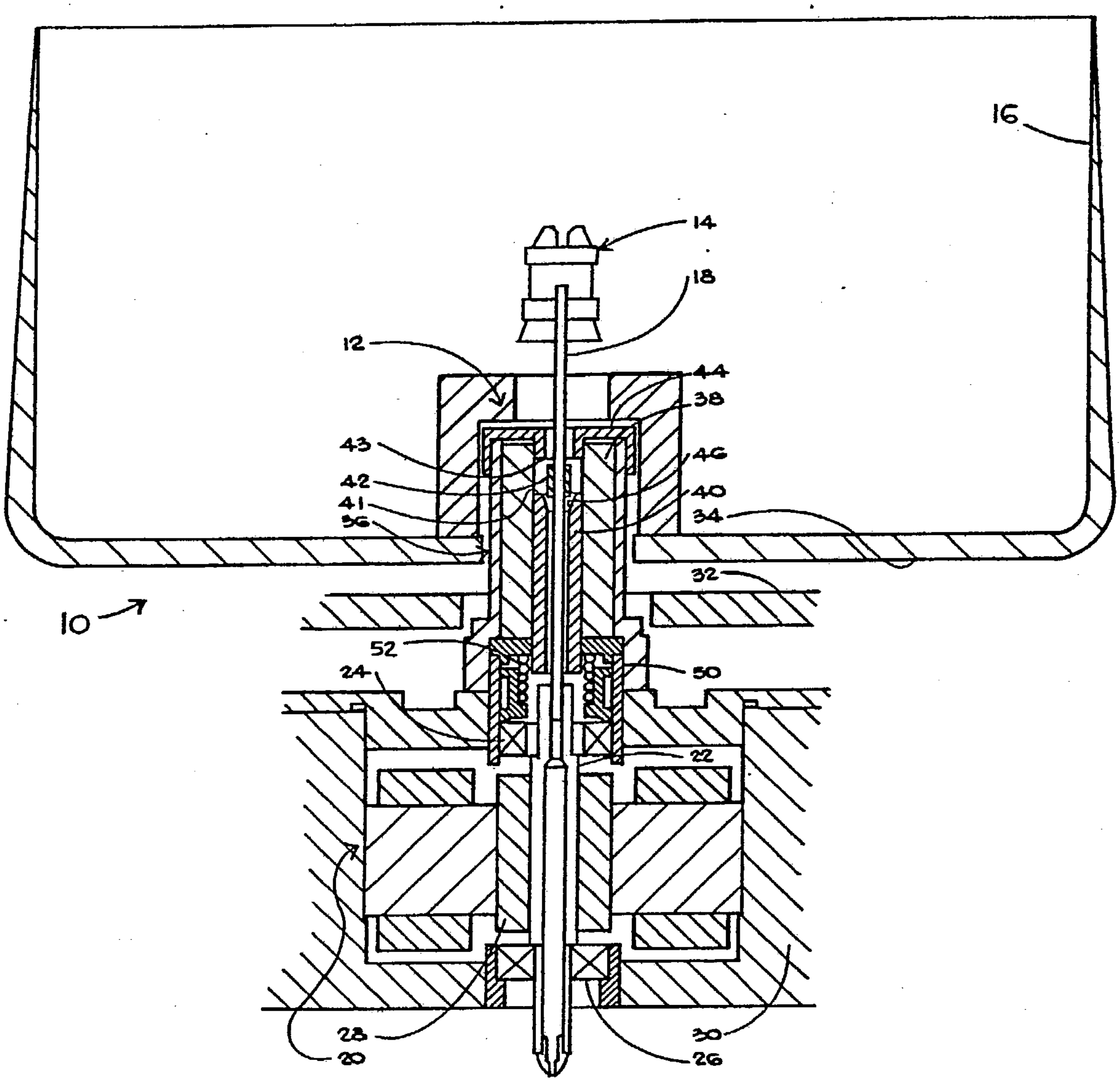

FIG. 1

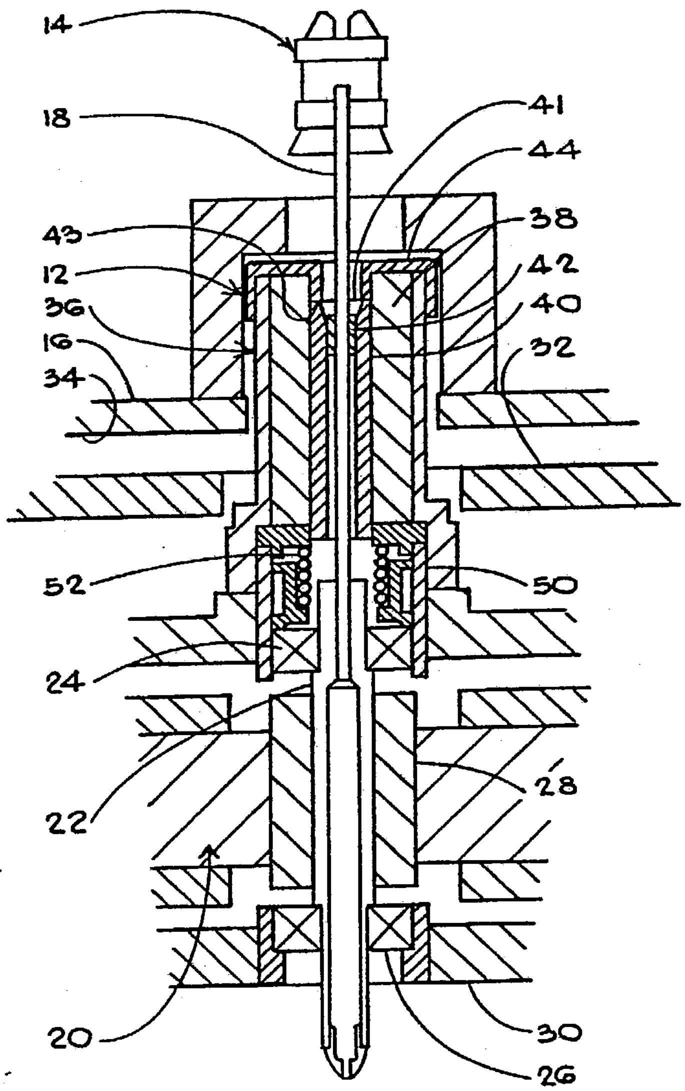

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 83/00402

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^3: B 04 B 9/12; B 04 B 9/14

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC^3	B 04 B; F 16 F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	GB, A, 1210038 (JANETZKI AND POMPER) 28 October 1970, see the entire document --	1,2,4,5,7,8
A	US, A, 3430852 (GRAESER AND LENKEY) 4 March 1969, see column 1, lines 26-44; column 3, lines 43-67; figure 2; column 5, lines 9-13 --	1-4,6,8
A	US, A, 2524678 (OLCOTT) 3 October 1950, see column 1, line 46 - column 2, line 11 and figures --	1,8
A	FR, A, 2359327 (AUGSBURG-NURNBERG) 17 February 1978, see page 6, lines 20-28; figures 5,6 -----------	

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
20th July 1983	10 AOUT 1983
International Searching Authority [1]	**Signature of Authorized Officer [20]**
EUROPEAN PATENT OFFICE	G.L.M. Kruydenberg

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/US 83/00402 (SA 5104)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 04/08/83

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
GB-A- 1210038	28/10/70	None		
US-A- 3430852	04/03/69	GB-A-	1199081	15/07/70
		DE-A-	1757724	29/06/72
US-A- 2524678		None		
FR-A- 2359327	17/02/78	NL-A-	7707142	24/01/78
		DE-A,C	2632586	26/01/78
		AU-A-	2719177	25/01/79
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